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ABSTRACT

Dealing exclusively with instructional computing, this paper describes how computers are delivering instruction in a wide variety of subjects to students of all ages and explains why computer-based education is currently having a profound impact on education. After a discussion of roots and origins, computer applications are described for educational, government, professional, and instructional markets. Examples of higher education applications are given for the sciences, the arts, humanities, medicine, agriculture, business, engineering and counseling, and for mathematics, reading, language arts, and computer science at the pre-college level. Examples of applications are from the PLATO system and include diagrams. Benefits and characteristics of computer-based instruction are enumerated and explained, and an overview of instructional computers on the current market is provided, including online mainframe systems, offline microcomputer systems, and hybrid systems. Six main categories of system-selection criteria for good computer-based instruction are discussed: (1) support for instructional strategies; (2) student learning station requirements; (3) features for instructors and authors; (4) general operational characteristics; (5) dissemination networks; and (6) future viability. Final sections examine contemporary trends and issues in the future related to computer-based instruction. Eighteen references are listed. (LMM)

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Computer-Based Instruction:

Roots, Origins, Applications, Benefits, Features, Systems, Trends and Issues

Fred T. Hofstetter
University of Delaware
October 15, 1981

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OUTLINE

Introduction

- Roots
  - man's historical use of machines
  - societal impact of computers
  - computers that teach
- Origins
  - internal use in the 1950's
  - university experiments in the 1960's
  - federal funding in the 1970's
  - affordability in the 1980's

Applications

- Higher Education
  - Science (example: chemistry)
  - Arts (example: graphic design)
  - Humanities (example: music theory)
  - Medicine (example: handling emergencies)
  - Agriculture (example: animal science)
  - Business (example: accounting)
  - Engineering (example: thermodynamics)
  - Counseling (example: career search)
- Pre-College
  - Mathematics (example: arithmetic and linear equations)
  - Reading (example: teaching survival words)
  - Language Arts (example: grammar and writing)
  - Computer Science (example: FORTRAN)
- Commercial
  - Government (example: FAA flight plans)
  - Professional (example: PCA review)
  - Industrial (example: Fundamentals of Hygiene)

Benefits of Good Computer-Based Instruction

- Individualized Instruction
- Expanded Educational Outreach
- Reductions in Learning Times
- Emphasis on the Intrinsic Joy of Learning
- Richer Intuitive Grasp of Complex Phenomena
- Access to Data for Checking Out Hypotheses
- Deeper Understanding through Modeling and Simulation
- Instruction Tailored to Meet Student's Own Objectives
- Immediate Feedback
- Anonymous Way of Asking Questions About Sensitive Issues

Characteristics of Good Computer-Based Instruction

Support for Instructional Strategies

- tutorial
- drill-and-practice
- simulation
- gaming
- problem solving
- testing
- computer-managed instruction

Requirements of the Student Learning Station

- high-resolution graphics
- programmable character sets
- animation
- touch input, light pen, cursor controls
- student control keys
- keyset overlays
- instantaneous response time
- support of peripheral devices

Features for Instructors and Authors

- program libraries
- indexes and routers
- student record keeping
- communication options
- programming aids

General Operational Characteristics

- reliability
- maintainability
- accessability
- ease-of-use
- security
- documentation

Dissemination Networks

- international program distribution
- communication links
- user groups

Future Viability

- corporate commitment to CBI
- flexibility of system design
- planned use of microelectronics

Instructional Systems on the Market Today

On-Line Mainframe Systems

IBM's Coursewriter
CDC's PLATO
Computer Curriculum Corporation
Hazeltine's TICCIT

Off-Line Microcomputer Systems

Apple
Atari
Bell and Howell
Commodore
Ohio Scientific
Osborne
Radio Shack
Texas Instruments

Hybrid Systems

MicroPLATO

Contemporary Trends in Computer-Based Instruction

Growth of Instructional Computing and Dollars Spent
Expansion of Lesson Libraries
Networking Experiments
Peripheral Development
Funding Patterns

Issues in the Future of Computer-Based Instruction

Decreasing Cost of Large Systems
Increasing Features of Small Systems
Distributed Versus Central Data Bases
Systematic Design Languages
Models for CBI Management
Emergence of a New Profession

FOREWARD

It is the purpose of this paper to provide an overview of the exciting field of computer-based instruction. After discussing its roots and origins, it is shown how instructional computers are being used in educational, government, professional, and industrial markets. The many student benefits of computer-based instruction are enumerated and explained, as are its characteristic features. An overview of instructional computers on the market today is provided for both large and small systems. The paper concludes with a discussion of the major trends and issues in the field of computer-based instruction.

Before beginning, it is important to define what is meant by the term computer-based instruction, which is also referred to by the abbreviation CBI. There are four types of computing with important principles of division setting them apart. These are administrative, research, instructional, and academic computing, respectively. The most easily identified type is administrative computing. This includes fiscal reporting, fixed asset accounting, inventory, library services, mailing lists, payroll, personnel, scheduling, and receivables. Research computing involves the manipulation of scientific data bases, modeling and simulating complex phenomena, and scientific number crunching. Instructional computing refers to the interactive use of the computer as a medium for delivering instruction. Academic computing includes all of the rest--supporting COBOL for business students, PASCAL and FORTRAN for science students, statistical packages for campus-wide use, and all those activities referred to as "general-purpose computing."

This paper deals exclusively with instructional computing, showing how computers are delivering instruction in a wide variety of subjects to students of all ages, and explaining why computer-based instruction is having a profound impact upon education as we know it today.

INTRODUCTION

Roots. Computer-based instruction is rooted in the inseparable historic involvement of man with his machines. Since man knows that he will inevitably die, he is necessarily a teacher (Weizenbaum, 1976). His inventions of the oar, the spear, the ship, the printing press, the clock, the telephone, and the radio are not only tools that have enabled him to transform his physical environment. They are also pedagogical instruments that will impart to succeeding generations his model of himself.

The most important machine in the hand of contemporary man is the computer. The adoption of technological innovations in the operation of science, business, and government is so widespread that many countries have become information societies increasingly dependent upon computers as a national resource (Molnar, 1978). Never before has man invented a machine that has become such an obsession for him. In 1980, Americans alone spent almost $3 billion in quarters to play outer space computer games.

Perhaps the most unique aspect of the computer is that in addition to performing the tasks for which it was invented, it can teach. The pedagogical use of the computer thereby differs in kind from that of man's other inventions.

Origins. Suppes (1978) tells how in the 1950's members of the computer industry programmed their machines to train their own employees. It was found that the ability of the computer to provide self-paced, individualized instruction with immediate feedback served a primary educational need that was not being met in the traditional classroom. However, these programs had to be written in machine language, a highly technical, numeric code used by computer professionals.

The development of high-level authoring languages in the 1960's opened up the field to educational institutions. In 1960, two important authoring languages were announced. COURSEWRITER, developed by IBM, was used at Stanford University in the mid-60's to test the feasibility of using computers to teach mathematics and reading in elementary schools. TUTOR was developed at the University of Illinois on CDC equipment and for two decades has been the authoring language of the PLATO system.

By the end of the 1960's, experiments at Stanford, Illinois, Florida State, Texas, Alberta, and the Australian National University showed that computer-based instruction had potential. In the 1970's, the federal government provided massive funding to educational institutions in order to realize this potential. The largest grants went to the University of Illinois for PLATO and to Brigham Young University for TICCIT (Time-shared, Interactive, Computer-Controlled, Information Television). Federal support was also used to continue the work at Stanford and to begin numerous curriculum development projects such as the work in physics by Alfred Bork at the University of California at Irvine. The government also supported the formation of a non-profit organization called CONDUIT through which educational computer programs could be distributed.

The microelectronic revolution of the late 1970's was welcomed by educators because it meant that the high price of computer-based instruction might fall within an affordable range. Indeed, it has, and the price is still falling. Now on the market at the beginning of the 1980's are a variety of large and small instructional computer systems. The large mainframe systems of the early 1960's, PLATO and COURSEWRITER, are now products of CDC and IBM, respectively, and their price tags are less than half of what they were then. TICCIT is being sold in a minicomputer version by Hazeltine. And the work begun at Stanford has evolved into a system sold by the Computer Curriculum Corporation (CCC).

In addition to reducing the price of large systems, microelectronics have also been used to make small, low-cost systems for use in schools and in homes. Referred to as "personal computers," sales of these small systems number in the hundreds of thousands. Radio Shack has opened computer stores for its TRS-80. Sears sells Atari personal computers and will soon open retail computer stores that will include IBM's new personal computer. Apple, TI 99/4, Commodore, Atari, and Ohio Scientific machines are sold through various catalogs and by a chain of small computer stores called Computerland in neighborhood shopping centers. It is no longer regarded as risky to predict that by the end of the century every home will have a personal computer. Knowing this, major textbook publishers are now preparing computer-based learning materials for use in schools and in homes, and mainframe vendors are working out ways in which personal computers can be used as terminals to access on-line data bases, down-line loading educational programs to home systems when needed.

APPLICATIONS

Perhaps the best way to understand the nature of computer-based instruction is to see it in action as it is being applied in the field. There are three principal markets for computer-based instructional materials today, namely, higher education, pre-college instruction, and commercial training. The rapidly decreasing cost of personal computers is also giving rise to a fourth market in home computing.

It will be the purpose of this section to provide an overview of the use of instructional computing in the three established markets. Each of these markets can be broken down into categories of applications. In higher education, these are science, arts, humanities, medicine, agriculture, business, engineering, and counseling. In pre-college instruction, the main categories are mathematics, reading, language arts, computer science, and enrichment. Commercial applications can be thought of in governmental, professional, and industrial categories.

It was noted above that the system that best fulfills the characteristics of good computer-based instruction is the PLATO system. In order to provide a look at the most advanced uses of instructional computing today, the following applications overview will be given using examples from the PLATO system. The overview is necessarily selective, as there are well over one hundred applications running on the PLATO system.

Science: Chemistry

During the 1970's the National Science Foundation funded the development of a large package of chemistry lessons at the University of Illinois. These lessons have replaced two-thirds of the lectures formerly given in freshman chemistry. Drill-and-practice lessons offer students the opportunity to review the principles of chemistry as much as is needed for firm comprehension. Diagnostic lessons check achievement levels and progress. Simulations allow students to work with many more samples than is possible in the traditional chemistry laboratory. Problem-solving lessons let students experiment with many methods of finding a solution.

Figure 1 shows a sample display from a distillation experiment. Students must first put the still together by touching a piece of the apparatus on the right and then touching where it goes on the column at the left. Interactive help is given when students make mistakes. After they have assembled the still, the students perform the distillation in a simulation that allows them to converse with PLATO in ordinary English. Figure 2 shows how PLATO tells the students when the oil bath gets too cool. The graph in the lower right corner shows distillation temperature versus milliliters distilled.

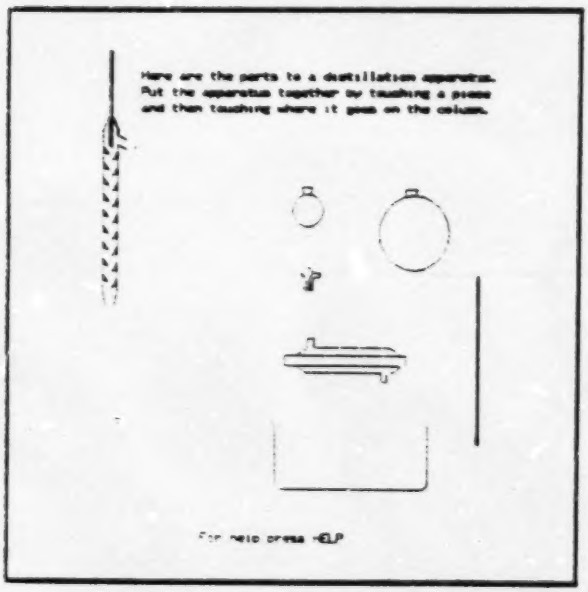

Figure 1. Functional Distillation Experiment by Stanley Smith. Copyright © 1975 by the Board of Trustees of the University of Illinois.

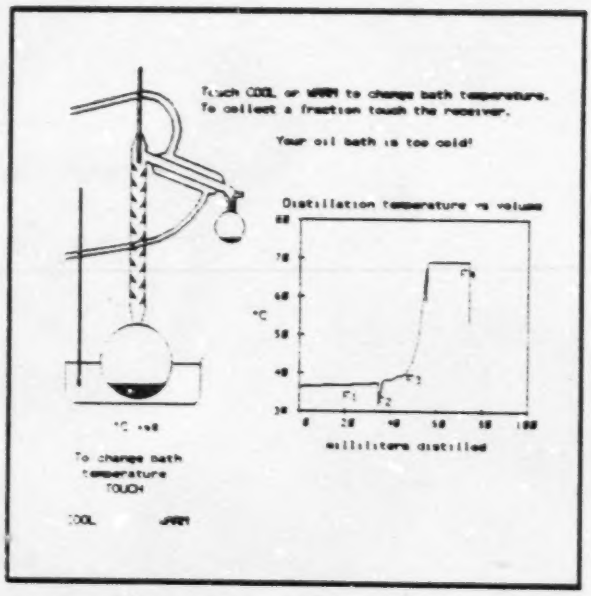

Figure 2. Functional Distillation Experiment by Stanley Smith. Copyright © 1975 by the Board of Trustees of the University of Illinois.

Arts: Graphic Design

Graphic design lessons are used in typography, basic illustration, advertising design, and portfolio preparation. Using the highly sophisticated graphics features of PLATO, students are interactively able to create and to alter designs on the terminal screen. Work which used to take fifteen hours to complete on paper can be done in three hours on PLATO, thereby giving students the opportunity to work many more problems than they could before. They are also developing a better aesthetic judgment, because the lesson makes it so easy for them to alter their designs. If they don't like part of a design, they have the capability to change that part while retaining the remainder of the design. Thus students are encouraged to make what they like rather than like what they make.

The main applications of PLATO in Art can best be explained by looking at how students use two programs, namely, "unit design" and "grey scale practice in tonal recognition." In the unit design program, the student enters a shape into the computer by either turning on or turning off dots on a 96 x 96 dot matrix. Figure 3 shows how the student creates the image by selecting options like "move," "delete point," "store," and "draw line." Next, the student uses the basic shape to form a composite image by performing graphic transformations of the basic shape. Figure 4 shows how the student creates the composite image by rotating, mirroring, and inverting the positive/negative relationships of each element.

Figure 3. Unit Design, by Ray Nichols; creating the basic image. Copyright © 1977 by the University of Delaware.

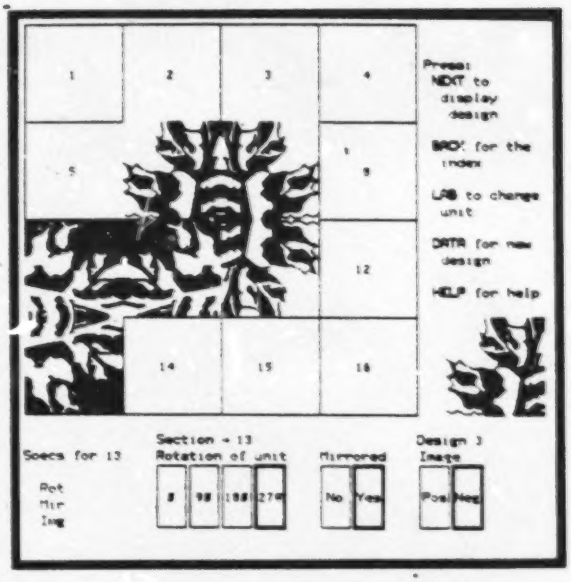

Figure 4. Unit Design, by Ray Nichols; creating the composite. Copyright © 1977 by the University of Delaware.

Through successive tries at designing basic shapes and performing graphic transformations, the student learns how to create clever and intricate designs such as the one shown in Figure 5.

The grey scale program gives Art students practice in recognizing the tonal values of the many shades of grey. This lesson presents the students with a grid of 20 x 30 squares. The student can then see the shade of grey for each square by telling PLATO the percentage of grey which should be in the square. Some students have become so adept at recognizing values of grey on PLATO that they can use the grey scale program to create facial images, such as the one shown in Figure 6.

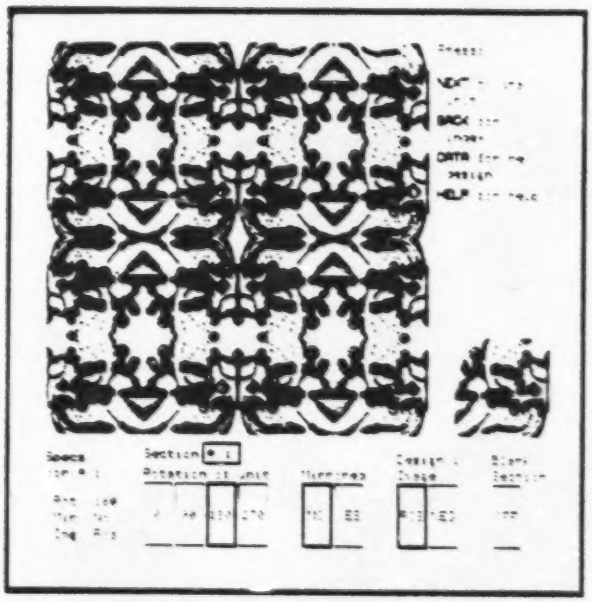

Figure 5. Unit Design, by Ray Nichols; the finished product. Copyright © 1977 by the University of Delaware.

Figure 6. Grey Scale, by Ray Nichols. Copyright © 1977 by the University of Delaware.

Humanities: Music Theory

A comprehensive package of music theory lessons is called the GUIDO music learning system. Guido d' Arezzo is the eleventh century musician and music educator who invented the staff and established the principles of solmization. Since he was the first real music educator, the system has been named after him, using his first name as an acronym for Graded Units for Interactive Dictation Operations. The GUIDO system consists of two main parts, namely, aural skills and written skills.

The first two years of music theory have been organized according to levels of difficulty into graded units which form the basis of a competency-based curriculum including drill and practice in intervals, melodies, chords, harmonies, and rhythms. Music students spend an average of two hours each week at GUIDO learning stations which consist of a PLATO terminal and a digital music synthesizer.

The basic design of the GUIDO programs consists of a three-part process whereby PLATO first displays an answer form on the terminal screen, second, plays a musical example using the digital synthesizer, and third asks questions about the students' perception of the example. PLATO keeps track of how well the students are doing and issues weekly progress reports to the instructors.

Figure 7 shows a sample display from the intervals program.

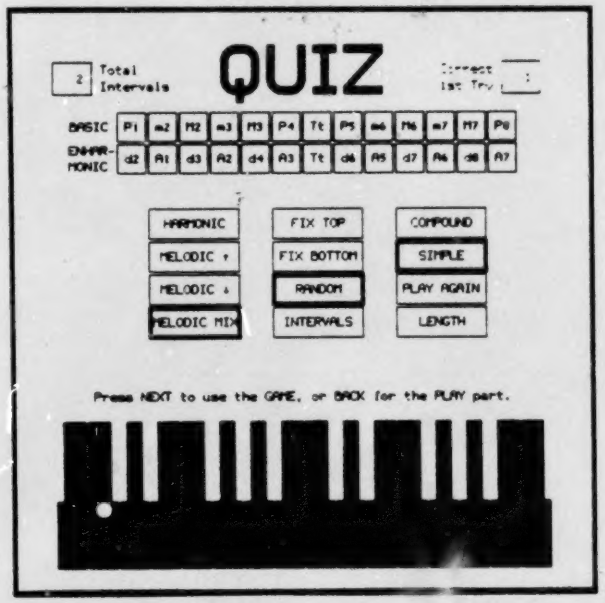

Figure 7. GUIDO Intervals Program, by Fred T. Hofstetter and William H. Lynch. Copyright © 1977 by the University of Delaware.

By studying this display the basic features of the GUIDO system can be understood. At the top are two rows of boxes which contain the names of musical intervals. When the student wants to hear an interval, all he has to do is touch one of the boxes. When he does, the box lights up and the interval designated by the box is played by the computer-controlled synthesizer. Conversely, when the student is going through one of GUIDO's formal units, the computer plays an interval, and the student responds by touching the box which contains the interval he thinks was played.

Underneath the interval names are three columns of teacher or student control boxes. These boxes are used to control the way in which dictation is given. The teacher can preset them for the student, or the teacher can allow the students to set them at will. The first column of boxes allows for the intervals to be played as harmonic, melodic up, melodic down, or melodic intervals up and down. The second column gives the option of being able to fix the top or bottom note of the intervals, or to have them selected at random. The box marked "intervals" allows the student to eliminate intervals from the boxes at the top of the screen, so that only some of the intervals will be played. In the third column of boxes the student can select compound or simple intervals, can have an interval played again, and can change the length of time the intervals last. Finally, there is a keyboard at the bottom of the screen. When intervals are played in formal units one of the notes of each interval is shown on the keyboard, and the student is asked to touch the other note played in the interval. In this way, students are quizzed on the spelling as well as on the aural recognition of intervals.

Medicine: Handling Emergencies

A comprehensive package covering pharmacology, anatomy, medical biochemstry, gynecology and obstetrics, medical parasitology, physiology, epedemiology, and medical problem solving comprises the PLATO medical library. In addition to tutorials, drills, and tests, the medical field has found the computer's ability to simulate illnesses and emergency situations to be especially helpful, because students can get much more practice treating illnesses and handling emergencies than they can in the classroom.

Figure 8 shows the scenario from a simulation of an emergency situation. An accident has occurred, and a patient is in dire need of emergency treatment. The student is faced with the problem of what to do. There are many options available to the student in this lesson. For example, at any time the student can ask to see the patient's vital signs by pressing the "vital signs" box at the bottom of the display. Figure 9 displays vital signs at the beginning of the simulation. The patient is cyanotic from lack of oxygen.

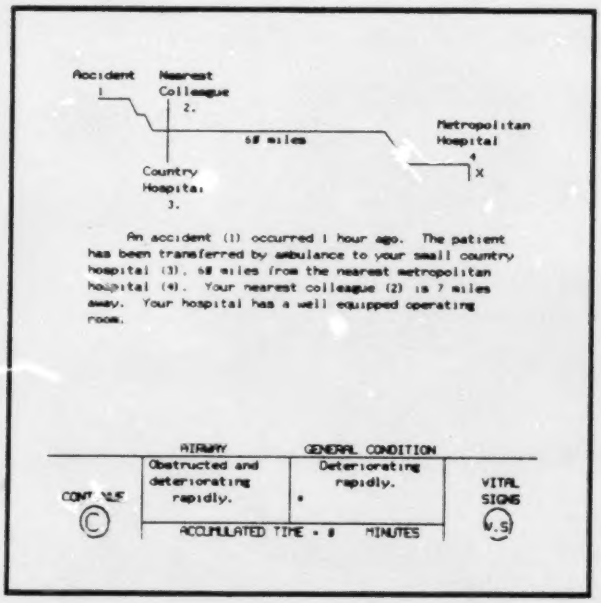

Figure 8. Emergency Patient Management Simulation by Wayne Osbaldeston, the R. S. McLaughlin Examination and Research Center of the Royal College of Physicians and Surgeons in Canada.

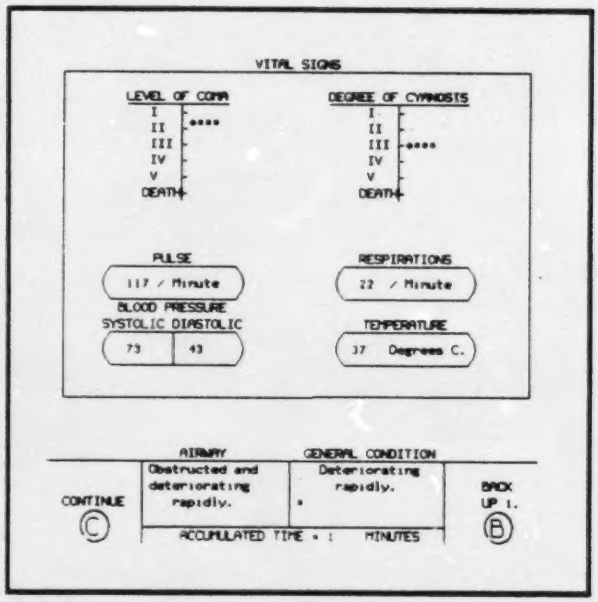

Figure 9. Emergency Patient Management Simulation by Wayne Osbaldeston, the R. S. McLaughlin Examination and Research Center of the Royal College of Physicians and Surgeons in Canada.

If the student initiates airway management options, the display shown in figure 10 appears. The student must perform a tracheotomy in order to completely relieve the airway.

In addition to having an obstructed airway, this patient is also bleeding to death with a fractured femur and a severe head injury. Saving the patient's live depends on initiating the correct treatment options at the proper times. Figure 11 shows the options available to the students in this simulation. At the end of the simulation, the student is graded on how well the patient has been treated. Even if the patient's life has been saved, a low score can result. For example, doing a spinal tap would have nothing to do with saving the patient's life, would use up valuable time, and would therefore lower the student's score.

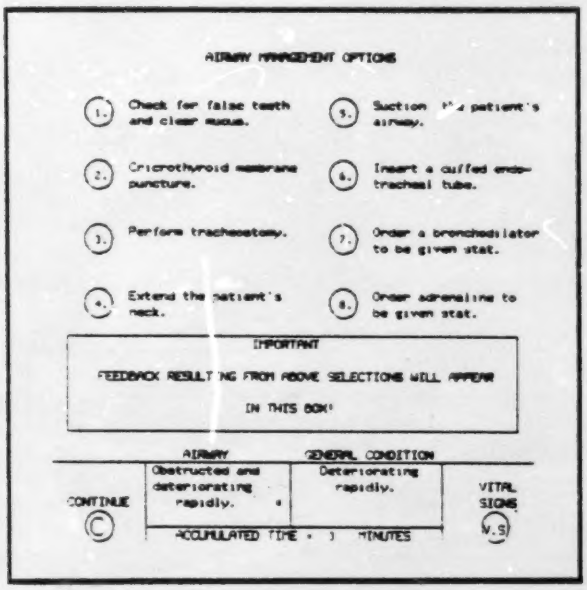

Figure 10. Emergency Patient Management Simulation by Wayne Osbaldeston, the R. S. McLaughlin Examination and Research Center of the Royal College of Physicians and Surgeons in Canada.

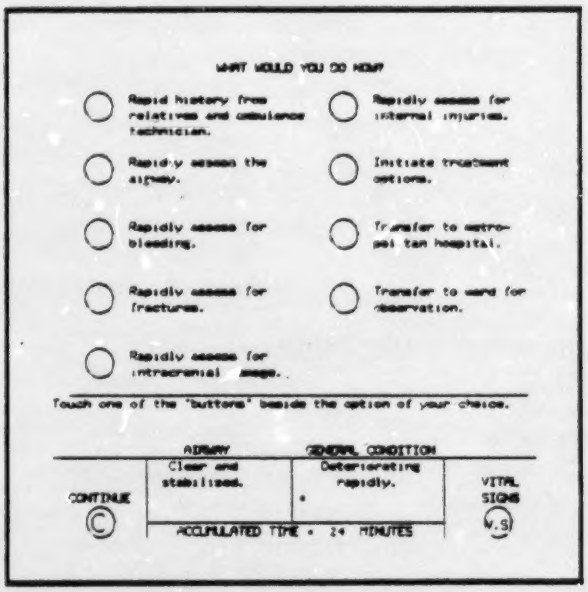

Figure 11. Emergency Patient Management Simulation by Wayne Osbaldeston, the R. S. McLaughlin Examination and Research Center of the Royal College of Physicians and Surgeons in Canada.

Agriculture: Animal Science

In Animal Science, beginning students are using PLATO to study veterinary terminology, principles of digestion, muscular movement, mechanics of breathing, neuron structures and functions, spinal reflex loops, eye anatomy, and elementary psychophysiology of audition. Advanced undergraduates study mitotic cell division, probability and heredity, drosophilia genetics, natural selection, mitosis, gene mapping in diploid organisms, blood typing, population dynamics, pedigrees, karyotyping, and DNA, RNA, and protein synthesis. Graduate students concentrate on meiosis and the anatomy and physiology of reproduction.

Figure 12 shows a sample display from the neuron structure and function program. PLATO simulates neurons with various internal structures. The student stimulates the neurons by pressing keys at the terminal and observes the effects of the stimulations as read by a recording voltmeter. The student can experiment with different rates and patterns of stimulation. PLATO keeps track of what the student does and provides the student with reports in the form of response graphs.

Another example of the use of PLATO in teaching animal science is taken from a series of lessons dealing with the endocrine system. After teaching terminology, definitions, and classifications of endocrine structures, PLATO presents the students with an outline of the human body and asks the students what endocrine structures they would like to see. Figure 13 shows how one student has asked to see the kidneys, and PLATO has responded by drawing the kidneys in the proper locations. Later on in the lesson, the body outline is drawn again with all of the structures drawn in their proper locations, and the student is required to correctly identify each structure.

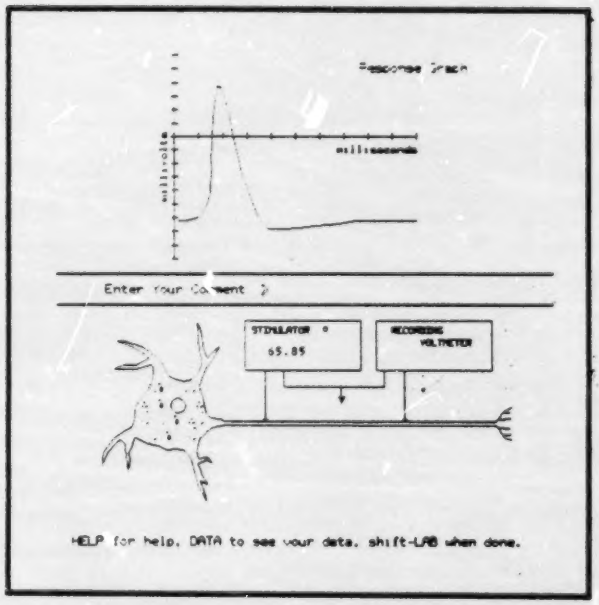

Figure 12. Neuron Structure and Function, by S. H. Boggs. Copyright © 1976 by the Board of Trustees of the University of Illinois.

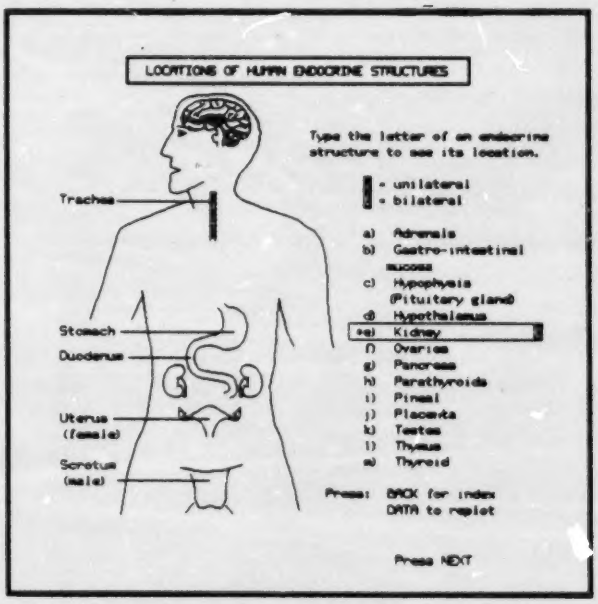

Figure 13. Endocrine System, by Paul Sammelwitz and Dan Tripp. Copyright © 1978 by the University of Delaware.

Business: Accounting

Teaching accounting is the largest single use of the PLATO system in higher education. Complete programming exists for the first two semesters of accounting, and this application is being extended into advanced courses. Figure 14 shows a sample display from a lesson on cost accounting and the break-even point. This lesson provides a graph of the break-even equation and asks the student to choose a point on the graph. Then the student is asked whether that point will result in a profit or a loss. As this process is repeated, students are shown how to fill in a chart that shows how much profit or loss is obtained from the various sales amounts.

Figure 15 shows the computation of the cost to manufacture one unit of product. The student is asked to compute the dollar values of the ending inventory of finished goods using absorption costing. Absorption costing along with direct costing are two types of cost accounting methods explained in this lesson.

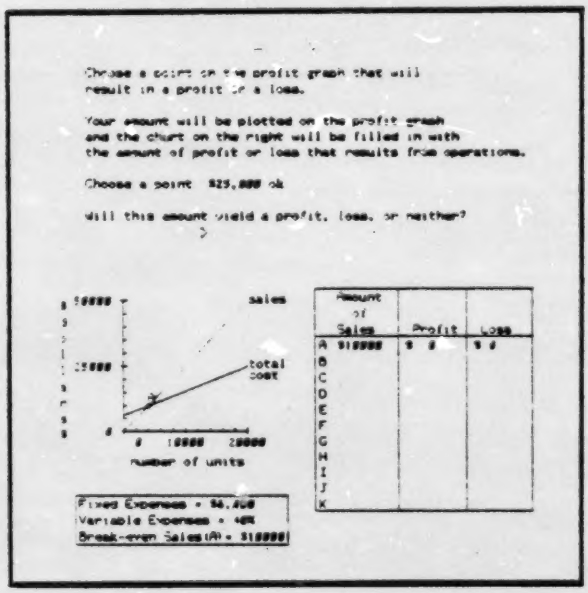

Figure 14. What is Break-Even Point? by Angelo Di Antonio and Louisa Bizoe. Copyright © 1979, 1980 by the University of Delaware.

Figure 15. Costing Methods, by Williams Childs and Jeff Gillespie. Copyright © 1979 by the University of Delaware.

Engineering: Thermodynamics

An important aspect of engineering education is the development of problem-solving skills. Since engineering students are such avid computer users, computer-based instruction is a popular medium for teaching problem-solving. For example, a package of thirteen lessons is used in a two-semester upper-division course sequence in chemical engineering thermodynamics. Figure 16 is part of a lesson which instructs the students on the use of an Othmer still to get vapor-liquid equilibrium data and then tests their abilities to analyze the data and to extract activity coefficients, to determine if the data are thermodynamically consistent, and to compare the activity coefficients with various theoretical models.

Figure 17 shows a sample display from a lesson on the Rankine Refrigeration Cycle, which teaches and tests the understanding of thermodynamic cycles and the reading of thermodynamic diagrams. Following an idealized Rankine refrigeration cycle on a pressure-enthalpy diagram, students learn how to calculate the coefficient of performance.

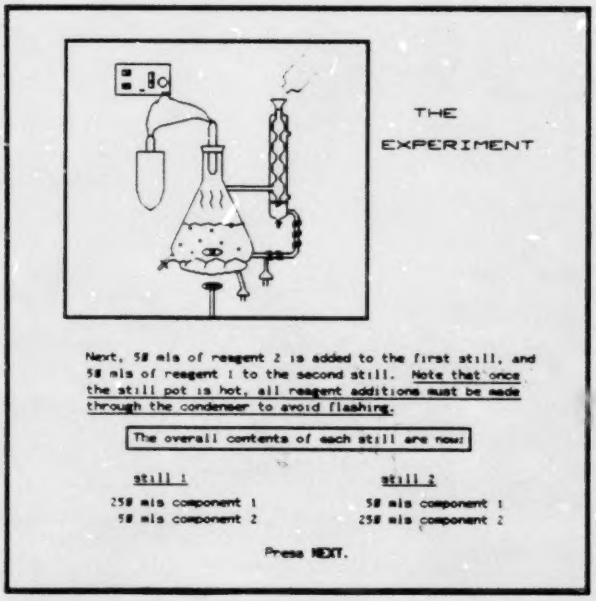

Figure 16. Modeling of Binary Mixtures, by Stanley Sandler and Douglas Harrell. Copyright © 1978 by the University of Delaware

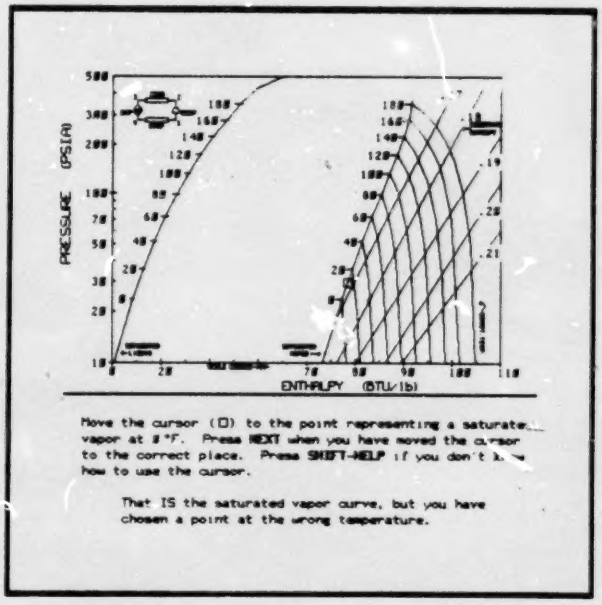

Figure 17. The Rankine Refrigeration Cycle, by Stanley Sandler, Robert Lamb, and Andrew Semprebon. Copyright © 1980 by the University of Delaware.

Counseling: Career Search

Computers are being used in career guidance to help students clarify thei interests and abilities, and to allow them to explore the characteristics of various occupations. A very popular program is a computerized version of John Holland's The Self Directed Search. The student begins by answering a series of questions in Holland's six scales, namely, realistic, investigative, artistic, social, enterprising, and conventional. Figure 18 shows a sample display from the investigative scale. In this scale, the student indicates whether the activities displayed on the screen are liked or disliked by touching the appropriate boxes. The boxes chosen by the student light up.

When the student completes The Self Directed Search, PLATO computes the scores for each of the six categories. After comparing these scores to a data bank of occupations, PLATO suggest some occupations and allows the student to ask questions regarding the occupations. In Figure 19 PLATO has been asked to display the employment outlook for the occupation "guidance counselor." The data bank contains current information on 317 occupations.

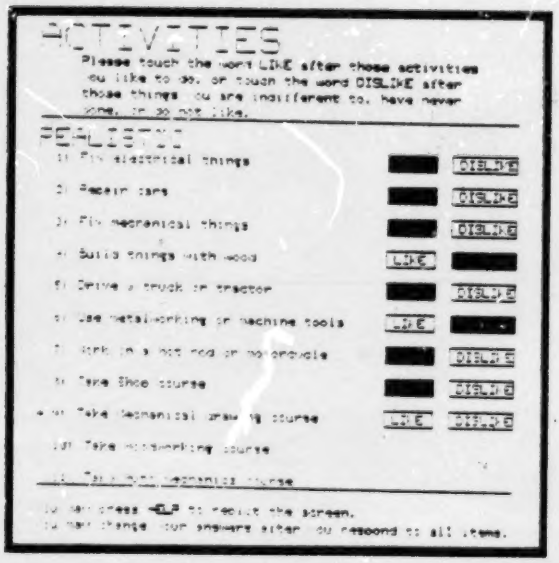

Figure 18. Interest Inventory from The Self-Directed Search, by John L. Holland. Copyright © 1977 by Consulting Psychologiest Press, Inc.

Figure 19. Occupational Search, by Richard Sharf. Copyright © 1977 by the University of Delaware.

Mathematics: Arithmetic and Linear Equations

A full range of mathematics lessons is available on the PLATO system, beginning with the Basic Skills Learning System that teaches elementary mathematics, continuing through the GED curriculum that teaches secondary school math, and culminating in calculus at the university level. Figure 20 shows a lesson called "Speedway" that is used in elementary schools. Speedway is a game-like lesson that provides students with drill and practice in number facts. The students first establish their skill levels in a practice race of ten problems in which a car moves along a race track to illustrate the amount of time they take to answer each problem correctly. PLATO points out all errors made on the first try. In the next race, the students are given positive reinforcement when they correctly answer a previously missed problem. If they are having difficulties, PLATO illustrates the problem with a picture. The students win the race if they have beaten their previous speeds; thus winning is based on self-improvement. Missed problems are presented again; when the students have mastered the problems at one difficulty level the advance to more difficult problems. Graphs and charts showing student performance are presented before and after each game.

Figure 21 shows a sample display from a lesson on the y-intercept that is used at the secondary level. PLATO presents open linear equations for students to complete as they wish, and then the graphical representations of the finished equations are displayed. Three lines have been displayed corresponding to the numbers 4, 0, and -2 that the student has entered into the equation.

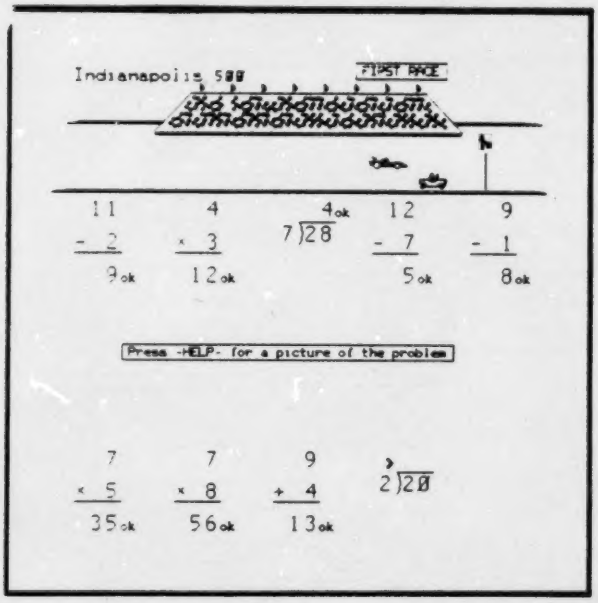

Figure 20. Speedway, by Bonnie A. Seiler. Copyright © 1974 by the Board of Trustees of the University of Illinois.

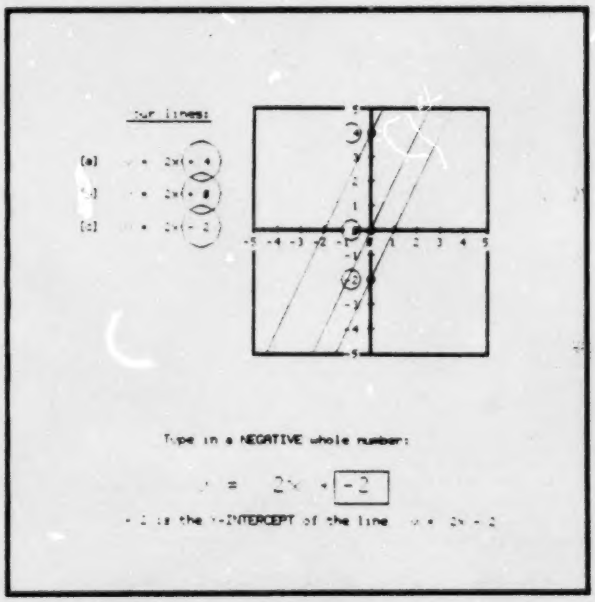

Figure 21. Intercept of a Straight Line, by Barbara Lederman. Copyright © 1976 by the Board of Trustees of the University of Illinois.

Reading: Teaching Survival Words

Four types of reading lessons have been written for PLATO. First, there are lessons that "read" stories to children by showing them pictures with sentences beneath them and speaking the sentences through a speech synthesizer when the students touch words on the screen. Many students have read their first complete story using this technique. Second, there are lessons that help teachers learn how to evaluate and record student progress in reading. Third, there are research lessons that present a story to students and record their answers to questions about the story. And fourth, there are lessons that teach students how to recognize individual words.

An example of this fourth type of reading lesson is SWAT (Sight Word Attack Team), which teaches survival words that an adult needs to be able to recognize in order to get through daily life. The lesson follows a motivational theme involving spies and secret passwords. Major activities in the lesson include:

1) watching an animated "briefing" on the word in the form of an amusing illustrated story containing the password in each sentence. Figure 22 shows a story on the word "stop" in which a car has stopped too late and has crashed into a bicycle that gets away undamaged;

2) selecting a password from among four foils to complete a "secret message." In figure 23 the student is asked to touch the word "telephone."

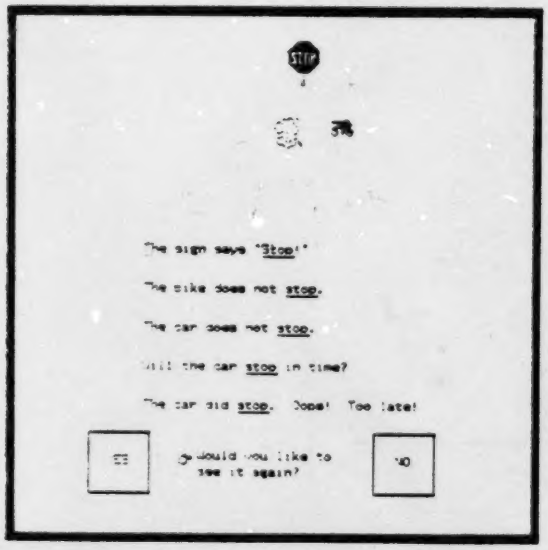

Figure 22. Animated Story from SWAT (Sight Word Attact Team) by Rosalie Bianco, Peter Pelosi, and Jessica Weissman. Copyright © 1978 by the University of Delaware.

Figure 23. Touch the Password from SWAT (Sight Word Attack Team) by Rosalie Bianco, Peter Pelosi, and Jessica Weissman. Copyright © 1978 by the University of Delaware.

3) decoding a message through spelling the password by touching letters on the decoder machine. In figure 24 the student is spelling the word "stop."

4) finding the password in a scramble of words. Figure 25 shows how the screen looks after the student touches four occurrences of the word "stop."

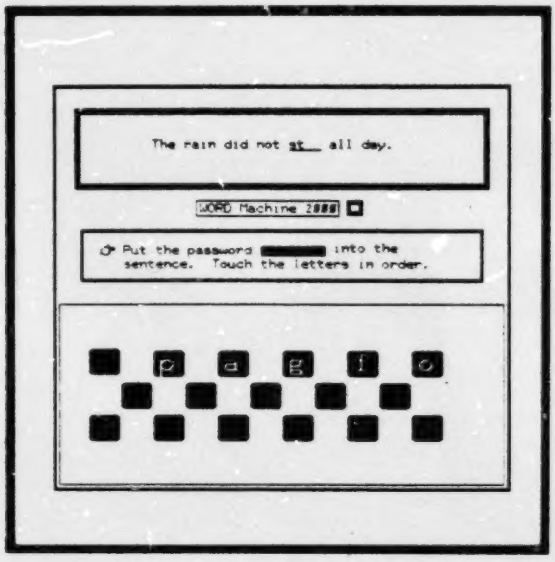

Figure 24. Spell the Password from SWAT by Rosalie Bianco, Peter Pelosi, and Jessica Weissman. Copyright © by the University of Delaware.

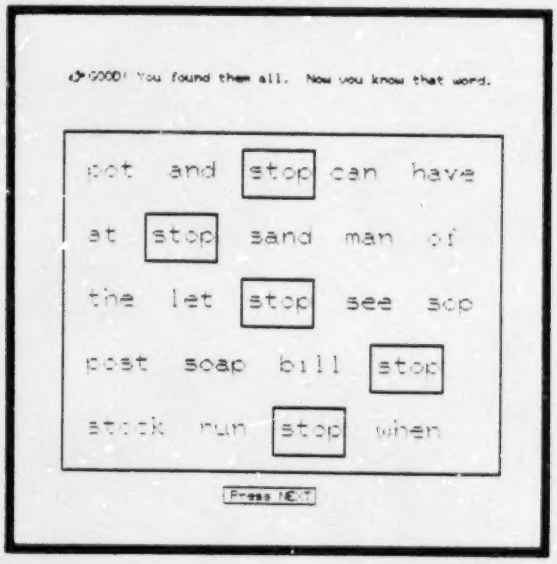

Figure 25. Finding the Passwords in SWAT by Rosalie Bianco, Peter Pelosi, and Jessica Weissman. Copyright © by the University of Delaware.

5) telling real spies from fake ones by deciding whether the sentence the spy is saying contains the password. In figure 26 the student is being asked whether the spy is saying the password "bank."

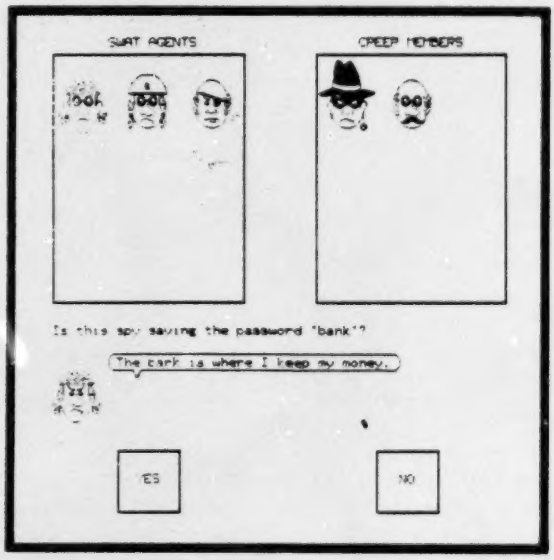

Figure 26. Identifying the Spy in SWAT by Rosalie Bianco, Peter Pelosi, and Jessica Weissman. Copyright © 1978 by the University of Delaware.

Language Arts: Grammar and Writing

Teachers have found PLATO to be a valuable tool for teaching punctuation, grammar, usage, and structure. Figure 27 shows a simple drill in which the student is asked to identify parts of speech in a sentence. In this example the student was first asked to indentify the pronoun in the sentence; the student correctly answered "their." The student was then asked to identify that pronoun's antecedent; the student correctly answered "children," and was appropriately congratulated. A special feature of this lesson is the interactive help that students receive when they answer incorrectly. In this example, if the student had answered "are" instead of "their," PLATO would have told him that "are" is a verb, not a pronoun.

Figure 28 shows a more complex exercise in which the student is given a paragraph that contains misused words. The student is asked to identify and correct the misused words. When a misused word has been corrected, PLATO crosses it out and prints the correct word above it. In the example given the student has already corrected the words "they're," "which," and "Irregardless," and is now changing "hisself" into "himself."

Figure 27. Pronoun Agreement, by Delores Lipscomb. Copyright © 1976 by the University of Illinois at Chicago Circle.

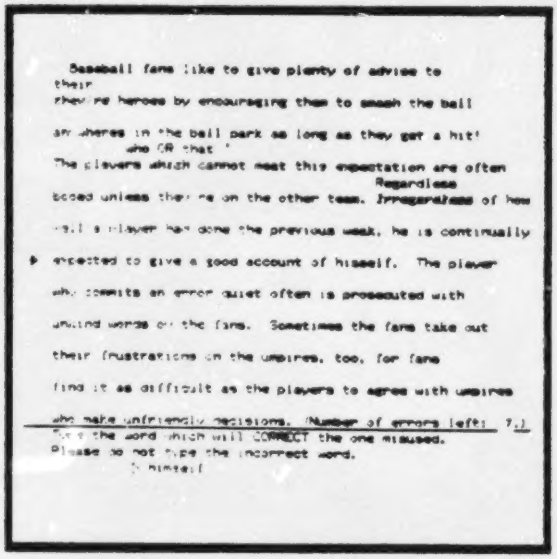

Figure 28. Paragraph Editing: Word Usage, by Errol M. Magidson and Mitsuru Yamade. Copyright © 1974 by the City College of Chicago.

Computer Science: FORTRAN

Computer science lessons on the PLATO system range from advanced topics, such as systems programming, numerical analysis, and information processing, to introductory lessons that teach what a computer is, basic computer terminology, and programming languages. These introductory lessons are being used increasingly in pre-college computer literacy courses. Shown below are two lessons that teach FORTRAN programming. In Figure 29, the students are given an "old program," and they are asked to retype it as a "new program" by compressing the if-statements together using Boolean constructs. So far, the student has written the third and fourth lines of the old program as one statement in the third line of the new program, and he is in the process of making the fifth, sixth, and seventh lines of the old program the fourth line of the new program.

Figure 30 shows how the PLATO system can simulate a FORTRAN compiler and help the students understand what the various statements do by allowing them to change their parameters and then observe their execution. In this example, the students are allowed to use four formating statements and two program execution statements. The students can edit the statements, enter data cards, initialize variables, and execute the program to find out the effects of their changes.

Figure 29. Experience with FORTRAN FORMAT Statements, by Rick Smkin and H. G. Friedman. Copyright © 1977 by the Board of Trustees of the University of Illinois.

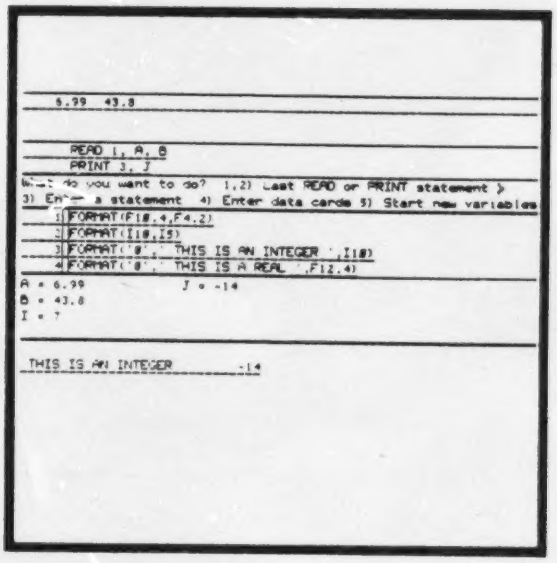

Figure 30. Understanding the FORTRAN IF Statement, by Greg Strass. Copyright © 1975 by the Board of Trustees of the University of Illinois.

Government: FAA Flight Plans

Since 1974, when the FAA Academy at Oklahoma City began using its first four PLATO terminals, the applications of computer-based instruction in aviation have grown to include flight inspection, electronics, powerplant and airframe maintenance, and pilot refresher courses. At present there are 35 terminals at Oklahoma City and 36 additional terminals at remote sites across the continental United States.

Figure 31 is a display from "RNAV Flight Plan," a lesson that teaches the operation of the area navigation computer in FAA aircraft through simulation of the computer's display panel. This lesson is part of a complete course on flight inspection procedures and techniques. Delivered in a computer-managed instruction format, this course is now producing about ten graduates each month.

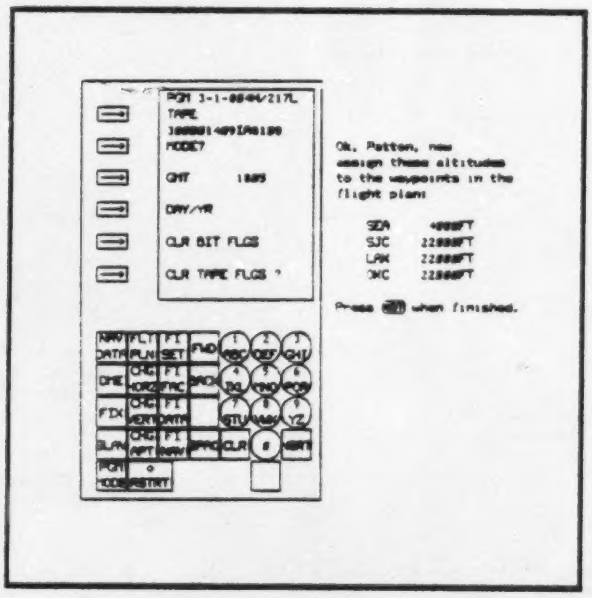

Figure 31. RNAV Flight Plan, by Craig Burson and Jim Duea. Copyright © 1978 by the FAA Academy.

Professional: CPA Review

An important use of PLATO is for the continuing education of professionals who have completed their formal education and must keep up with their fields while on the job. An example of courseware in this area is the CPA review that was programmed to help accountants prepare for the Uniform CPA Examination. Twelve thousand questions taken from previously administed CPA exams comprise the item bank. The questions are organized according to objectives in which the students take practice tests. If the students score lower than 85% on the tests, PLATO prescribes learning resources in the form of readings and other PLATO lessons with which the students can learn the material in order to prepare for trying the test again. If the students score 85% or higher, they are considered to have mastered the objective, and PLATO moves them ahead to the next objective. Figure 32 shows a sample question asked by PLATO in the CPA review, and figure 33 is a sample display from one of the learning resources.

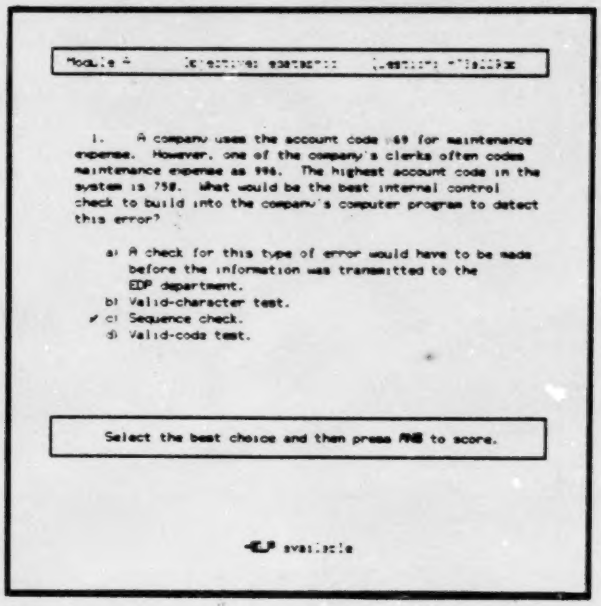

Figure 32. CPA Review, by Angelo Di Antonio. Copyright ©1979 by the University of Delaware.

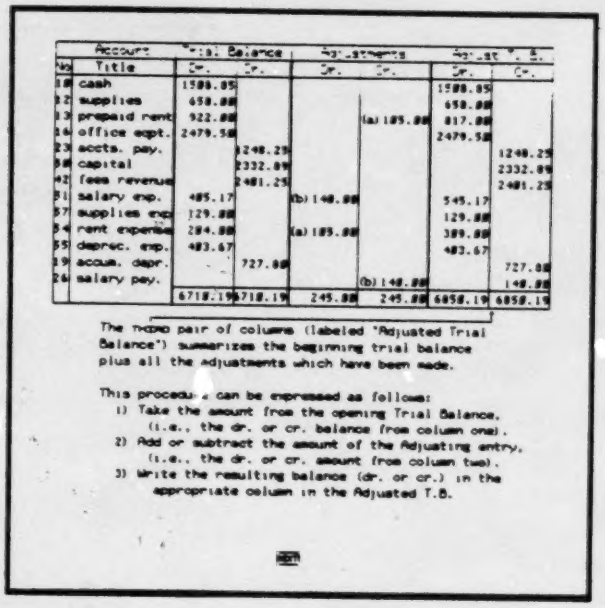

Figure 33. Worksheets, by James C. McKeown. Copyright ©1978 by the Board of Trustees of the University of Illinois.

Industrial: Fundamentals of Industrial Hygiene

Training costs are especially high in industry. Large companies are turning to computer-based instruction as a means of lowering this cost by reducing the amount of time needed for instruction, reducing travel costs by installing terminals in plants and laboratories, and scheduling fewer traditional classes. Topics covered include operations, plant safety, motivation, management, and customer training.

An example of the use of computers in industrial training is a lesson on the fundamentals of industrial hygiene. It is very important for employees to be able to recognize, evaluate, and control those environmental stresses arising in or from the workplace that may cause sickness, impaired health, or significant discomfort and inefficiency among workers or in the community. This lesson introduces employees to the four kinds of hazards, namely, chemical, biological, physical, and ergonomic. Figure 34 is from a tutorial on toxicity. After explaining the terms in the chart, PLATO shows some graphs and asks questions about them to make sure that the employees understand the concept of toxicity. Figure 35 is a sample display from one of these questions.

Figure 34. Fundamentals of Industrial Hygiene by the Occupational Environmental Control Engineering Service Division. Copyright © 1980 by E. I. DuPont de Nemours and Co., Inc.

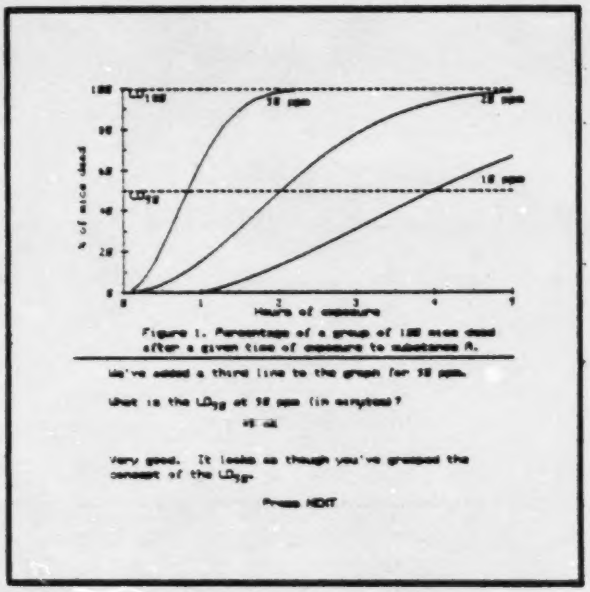

Figure 35. Sample question from Fundamentals of Industrial Hygiene by the Occupational Environmental Control Engineering Service Division. Copyright © 1980 by E. I. DuPont de Nemours and Co., Inc.

BENEFITS OF GOOD COMPUTER-BASED INSTRUCTION

In the introduction to this paper it was discussed how the field of computer-based instruction has grown considerably since its origins in the 1950's. There are now dozens of authoring languages, hundreds of applications, and thousands of hours of computer-based learning materials. Throughout this period of growth, teachers and students alike have identified many benefits of good computer-based instruction. It is through the realizaton of these benefits that CBI is receiving such widespread support and acceptance in education today. The benefits that have been recognized so far can be classified according to ten main purposes that are enumerated and explained as follows:

1. To individualize instruction. Faculty members and students often complain that the level of instruction is never right for all members in a class. Some are fast learners; others are slow learners. Some drop out because a course is too boring; others drop out because they can't keep up. The individualized, self-paced approach of CBI has proven to be a remedy for this problem of individual differences.

2. To expand the University's educational market. The market needs a delivery system that can economically deliver instruction over a wide geographical area. Through computer-based techniques, Universities can reach more students. For example, if three people in remote locations wanted to learn Persian, PLATO could teach them whereas a regular course would be cancelled because of small enrollment. This aspect becomes even more important as the learner population is becoming more adult in its makeup.

3. To reduce the time needed for instruction. Computer-based, self-paced techniques make it possible for students to finish courses in less than the normal fourteen-week semester. Students could complete their degrees ahead of schedule, thereby reducing the cost of instruction to the parent and the taxpayer.

4. To emphasize the intrinsic joy of learning and deemphasize competition with peers as a motivating force. In the computer-based environment the anxieties associated with the traditional classroom are minimized. Students are free to respond as they wish without fear of ridicule from either their peers or their teachers. In such an environment learning is a lot of fun, and motivation is high.

5. To enable students to develop a richer intuitive grasp of complex phenomena through graphic visual representation. Especially applicable to PLATO is the saying that "A picture is worth a thousand words." The ability of PLATO to create interactively a display suited to the student's specific learning needs cannot be overestimated.

6. To provide students with access to a wide range of data for checking out hypotheses. A good example of this benefit is CONDUIT's

population dynamics program. Stored in the computer are up-to-date data on the populations of countries throughout the world. The student is able to set variables which affect the futures of those populations, such as time and extent of famines and can then see the effects of those variables upon future generations of the populations.

7. To enable students to learn more of the complexities of phenomena through modeling and simulation. In addition to giving students drill-and-practice and tutorials on various sujects, computers can also allow the student to create models and to simulate complex phenomena. For example, the student can make electronic circuits, design clothes, compose music, draw pictures, mix chemicals, breed fruit flies, and then study the results of the models and simulations. Such flexibility is not a regular part of education in university courses; it should be.

8. To encourage students to tailor their learning experiences to meet their own objectives. How often do students complain that they did not get what they wanted out of a course? They may have met the instructor's objectives, but they did not meet their own objectives. Computers can help them do both. For example, in advanced music theory courses, very little time is spent on set theory. However, some students want to explore it in depth. It is a complex analytical system which cannot be learned by the average student by reading a book. Interactive instruction in this area is made available to the students who want it by means of PLATO's set theory program. There are ten hours of of instruction available for students who want to learn set theory, including periodic tests which assure the students that they are mastering the material. In this way, students are encourged to extend their learning beyond the requirements of the course.

9. To give immediate feedback. One of the greatest advantages of computer-based techniques is immediate feedback. Through individual interaction with the computer, the students partake in a dialogue in which they receive instantaneous responses to their input. There is no other medium which provides this interaction, a benefit which has led to the documentation of significant improvement of instruction in such diverse areas as anesthesiology, French, music, mechanics, dentistry, sociology, calculus, geography, ecology, health, physics, and accounting.

10. To provide students with an anonymous way of asking questions about sensitive matters. Recent research has shown that the use of anonymous sign-ons whereby students can use PLATO without revealing their identities has encouraged students to ask questions and get responses on sensitive issues which they would normally be afraid to discuss. PLATO's group notesfile capabilities enable students not only to ask questions and to get responses on their own personal questions, but also to see the questions and responses anonymously written by other students Especially in the area of sex education this has proven to be an excellent means of allowing students to anonymously explore sensitive personal issues.

CHARACTERISTIC FEATURES OF GOOD COMPUTER-BASED INSTRUCTIO

A dilemma is faced by anyone who contemplates the purchase of an instructional computer today, whether it be large or small. There are dozens of systems from which to choose, and no two systems have the same set of features. In order to decide what system to buy, the consumer needs to know what features are needed for his applications. There is a set of features that is characteristic of good computer-based instruction. Table 1 shows how these features can be thought of in six main categories. Each of these categories is discussed in turn as follows.

TABLE 1

SYSTEM SELECTION CRITERIA

1) Support for Instructional Strategies
   - tutorial
   - drill-and-practice
   - simulation
   - gaming
   - problem solving
   - testing
   - computer-managed instruction
2) Requirements of the Student Learning Station
   - high-resolution graphics
   - programmable character sets
   - animation
   - touch input, light pen, cursor controls
   - student control keys
   - keyset overlays
   - instantaneous response time
   - support of peripheral devices
3) Features for Instructors and Authors
   - program libraries
   - indexes and routers
   - student record keeping
   - communication options
   - programming aids
4) General Operational Characteristics
   - reliability
   - maintainability
   - accessability
   - ease-of-use
   - security
   - documentation
5) Dissemination Networks
   - international program distribution
   - communication links
   - user groups
6) Future Viability
   - corporate commitment to CBI
   - flexibility of system design
   - planned use of microelectronics

Support for Instructional Strategies. There are a variety of instructional strategies that can be used in designing educational computer programs. Some systems are quite limited in their support of instructional strategies. TICCIT, for example, is designed around a preselected strategy of objectives, examples, practice problems, and tests (Jones, 1978); for some applications this strategy may be appropriate, but there are many others that TICCIT cannot do. It is important for an educational system to support the gamut of instructional strategies that include tutorials, drills, simulations, games, problem solving, testing, and computer-managed instruction.

Requirements of the Student Learning Station. Careful attention must be paid to both the quantity and the quality of the features of the student learning station. Not only is the learning station the only part of the system that the student sees, but it also greatly affects how instructional materials are prepared. The resolution of dots on the display screen is an important consideration because it limits how much text can be displayed at one time as well as how many points can be used in making graphics. Sugarman (1978) has indicated that a resolution of 512 dots across by 512 dots down is certainly adequate, and that a resolution of 320 by 240 may also be adequate. At this lower resolution, which is typical of systems using ordinary TV displays, 16 lines of 40 characters each would fill the screen, whereas at the higher resolution 32 lines of 64 characters can be used.

Figure 36 shows a chemistry display made with a resolution of 512 by 512, and figure 37 shows one from the same subject made with 320 by 240 dots. The difference in quality is obvious. At the higher resolution, an apparatus, a graph, and student instructions can be given. At low resolution, just a graph nearly fills the screen.

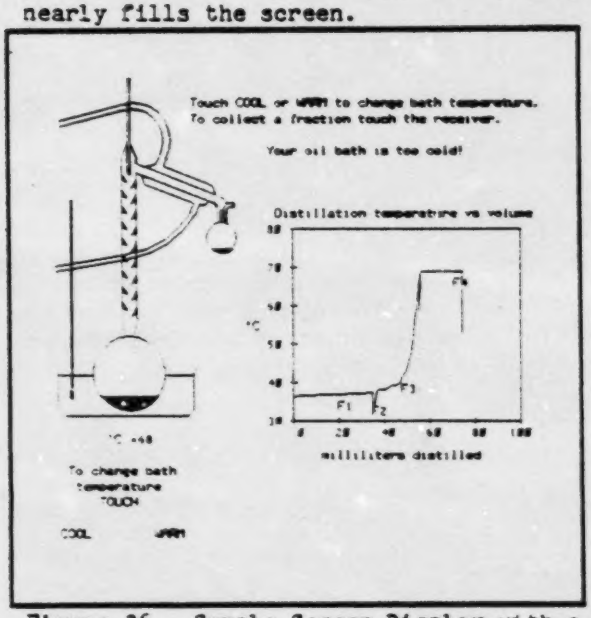

Figure 36. Sample Screen Display with a Resolution of 512 x 512 Dots. From Functional Distallation Experiment, by Stanley Smith. Copyright © 1975 by the Board of Trustees of the University of Illinois.

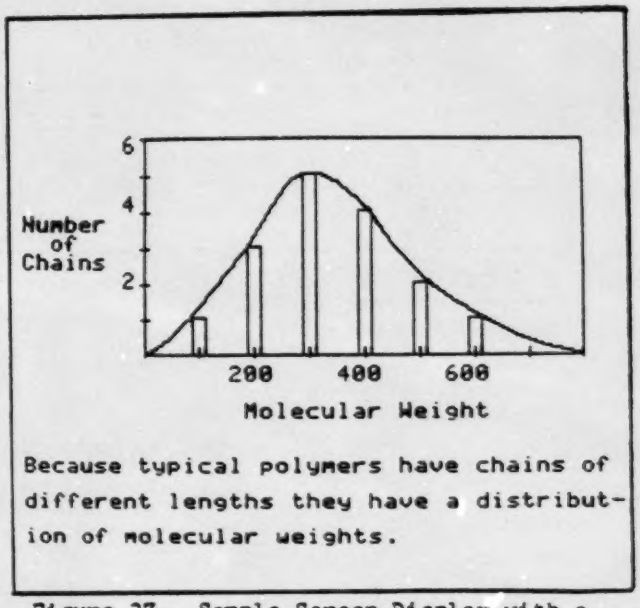

Figure 37. Sample Screen Display with a Resolution of 320 by 240 Dots. From Introduction to Polymers, by Stanley Smith, John Pochan, and Harry Gibson. Copyright © 1981 by The American Chemical Society.

In order that the system is not restricted to those characters and symbols that appear on the typewriter keyboard, there should be auxiliary memories where new characters can be defined. This makes it possible for educational programs to be written in foreign languages such as Greek and Persian, and for symbols used in the various academic disciplines to be used as characters in the terminal. Figure 38 shows how musical symbols can be displayed using programmable character sets.

System response time should be instantaneous so that students never have to wait, and the system should also be fast enough to move characters around on the screen. Figure 39 shows a sample display from an elementary reading lesson in which students learn how to make sentences of their own. The student has correctly entered the sentence "The boy runs over the rabbit from the house to the girl," and the sentence has been animated. The blurred figure is the boy moving across the screen in the animation.

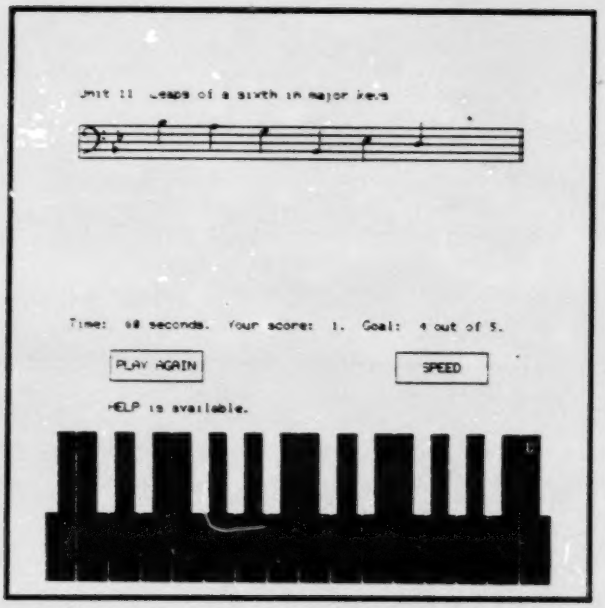

Figure 38. GUIDO Melodic Dictation Program by Fred T. Hofstetter and William H. Lynch. Copyright © 1979 by the University of Delaware.

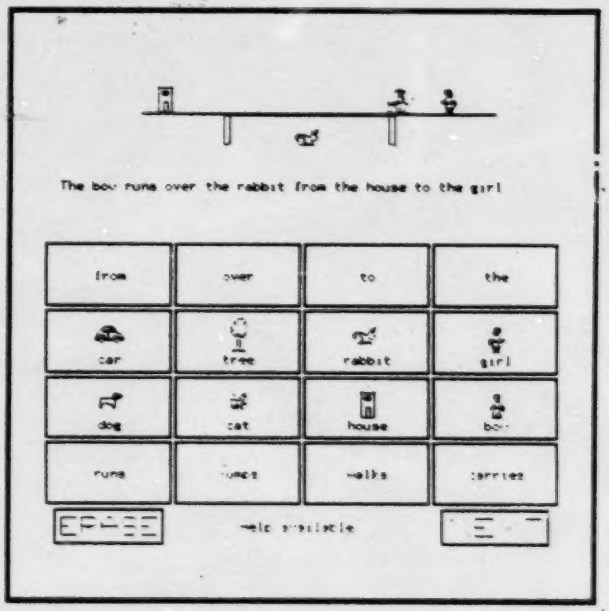

Figure 39. Make a Sentence by the PLATO Elementary Projects Group. Copyright © 1979 by the Board of Trustees of the University of Illinois.

Whereas all of the features of the student learning station are important, perhaps the ones that are most crucial to the ease of human interaction with the computer are the use of a touch panel, light pen, and/or cursor controls. Instead of making the student type mnemonic codes on a keyset, these devices allow students to indicate their answers to questions directly by simply touching the screen with their fingers or with a light pen, or by positioning a cursor over the answer. Both of the lessons shown in figures 38 and 39 use touch. A related feature is the keyset overlay whereby the symbols drawn on the computer keyboard can be changed to fit those used in a given subject.

Whereas touch panels and light pens make it possible for students to interact directly with the display without having to type on the keyset, the keyset should contain special control keys like NEXT, BACK, HELP, EASIER, HARDER, and ANSWER so that students can have some say as to the sequencing of lesson material. Just as the computer should never rush the student, neither should it make them wait; response time should be as instantaneous as possible. Instantaneous response time allows students to play notes on the piano keyboard shown in figure 38 in real time.

The features of the student learning station discussed above offer a lot of capability to the student. However, there are other devices that can enhance the computer-based learning environment, and by making available a special input/output port at the back of the learning station, peripherals can be attached. Music synthesizers, real-time clocks, bit-pads, torque analyzers, heart-rate monitors, pitch detectors, speech synthesizers, videodiscs, electronic test equipment, and random-access slide projectors, tape players, and microfiche units have already been interfaced to student learning stations.

Features for instructors and authors. Often neglected in system selection are the features that make it both easy and less time-consuming for instructors and authors to prepare lesson materials and to manage student records. It is widely recognized that the greatest cost in computer-based instruction is the design, programming, and evaluation of instructional materials. Important criteria in system selection are therefore the availability and the quality of pre-existing materials organized into lesson libraries, indexing systems whereby instructors can select and structure courses around these materials, programming aids whereby instructors can quickly get help when they have questions, communication options whereby instructors, authors, and students can share information regarding lesson development, and student record keeping that allows instructors to collect data on student achievement and progress in a lesson. Regarding student record keeping, it is important for the system not only to make available standard, pre-programmed ways of keeping student data, but also to allow the instructors to design their own ways of collecting and summarizing student records. Figure 40 shows a sample display from an instructor-designed record summary in a competency-based course. Column one normally shows student names, but in protecting the privacy of the students, numbers have been shown in this article. The next fourteen columns correspond to the instructional units in the course, and stars in these columns indicate that the students have mastered a given unit. The last column in the table shows how many minutes the students have spent trying to master units in the curriculum. Instructors can obtain reports such as these as often as they want, obtaining a graphic portrayal of the individual differences among students in their classes.

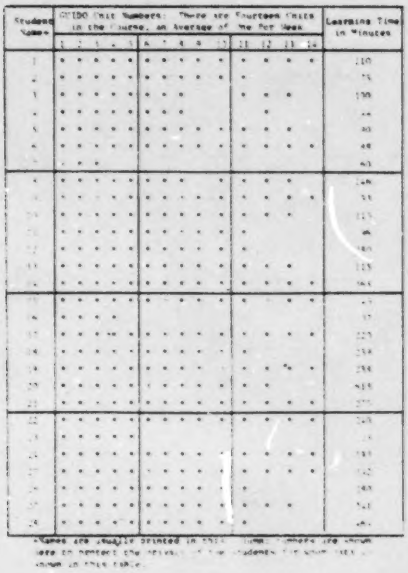

Figure 40. Sample Student Progress Report. "*" indicates mastery in a unit.

General operational characteristics. Instructional computing services must be reliable. Down-time must never exceed five percent of scheduled hours in any one month, and annual up-time should average at least ninety-seven percent. Mean time to failure should not average less than six days. Maintenance support must be readily available so that equipment problems can be solved promptly when they occur.

Students, instructors, and authors need to be able to schedule terminal time when they need it. Especially if a centralized approach utilizing one large computer is adopted, care must be taken to insure that various user groups do not compete for the same resources. There must be a way of allocating memory and processing time so that no single group can usurp resources belonging to another. Instructional computers must be easy to use. Human engineering, the effort made by computer vendors to make their equipment easy to use, is an important consideration in system selection.

There must be an adequate system of passwords, security codes, and file safeguards in order to insure that information cannot be obtained by persons who are not allowed access to it. The system must prevent access to persons trying to use accounts, user numbers, and sign-ons that are not their own. All users need system documentation that is complete, up-to-date, and correct. Indexes and libraries of published programs reflect the extent to which a given system can be used, and they make it possible to project the amount of programming that may have to be done locally. The number, extent, power, and ease of use of available programming languages are important system selection criteria, as are staff training programs offered by vendors in how to use available software packages and programming languages.

Dissemination networks. One of the greatest problems encountered in education today is dissemination. For a variety of complex reasons there is a resistance to using materials developed elsewhere. It is important for vendors of instructional computers to make available dissemination networks whereby materials can be published, exchanged, reviewed, and shared. Electronic links among major development sites facilitate the preparation of materials that are suitable for inter-institutional use, as do peer review mechanisms and user groups.

Future viability. Evidence of long-range corporate plans and commitments to the systematic development of curricular materials is just as important in selecting a system as is the evidence that the hardware can be upgraded to remain compatible with technological advances. Flexibility is a key term. Educational programs that allow instructors to select local terminologies and to adjust levels of dfficulty and sequencing of material for different groups of students will be more widely applicable than those in which instructional variables cannot be changed. Hardware must be designed for the future. Rapid changes in microelectronics have made it necessary for computer hardware to be both modular and redefinable. Upward compatability and expandability are vitally important to its long-range viability.

EDUCATIONAL SYSTEMS ON THE MARKET TODAY

On-line mainframe systems. In the introduction to this article, IBM, CDC, CCC, and Hazeltine were all mentioned as having mainframe systems on the market today. Having discussed the characteristics of good computer-based instruction, we can now be more critical of these systems. During the 1960's and 1970's, IBM supported the 1500 system, which had most of these characteristics. However, IBM has since discontinued the 1500 system, and its only current offering in this field is the Interactive Instructional System (IIS), an inadequate substitute that does not even have graphics. IBM is capable of much more, and perhaps with its new personal computer it will take a more creative approach to educational products. CDC, on the otherhand, views education as a big business. CDC has invested tens of millions of its own dollars in productizing and marketing PLATO, which is now an international network with systems in fourteen countries. PLATO meets all of the characteristics given in Table 1 except for keyset overlays.

The PLATO system is not yet profitable for CDC. The current projection is for PLATO to turn a profit in 1985. Quite the opposite is the case with the Computer Curriculum Corporation. CCC is making a big profit in the public school sector. It has documented proof that students who spend just ten minutes per day in its competency-based drills learn significantly more than traditional students--and this in a system that is based on the technology of the sixties with no graphics. TICCIT has found its primary market in the military where its built-in instructional strategy has proven to be effective. The most distinctive feature of TICCIT is its ability to show videotapes on the screen of the student learning station.

Off-line microcomputer systems. Apple, Atari, Commodore, Ohio Scientific, Osborne, Radio Shack, and Texas Instruments all have popular products in this area. Apple may seem to have the lead at the moment in education, if one considers the numbers of programs written and systems used in schools. Apples are also sold in the PASS system under the Bell and Howell nameplate. However, one of Apple's primary claims to fame, namely, its use in the Minnesota Educational Computing Consortium (MECC) where there are over two thousand Apples in use today, has eroded to Atari, which has won the MECC bid for the next three years. With its multi-processor graphics chip set, Atari is definitely a company to watch.

Commodore has introduced a new, low-cost version of the PET called the VIC, which costs less than $300 and uses an ordinary television set for a display. Ohio Scientific micros are now being sold in CDC's retail computer stores, and there is much conjecture about the future relationship between those two companies. The Osborne, a relative newcomer to the personal computer scene, is a portable computer that can run on batteries and fits under the seat of an airplane. Radio Shack offers perhaps the highest level of technical support for its personal computers, using each one of its stores as a retail outlet and return point for maintenance, and having recently opened a new chain of "computing centers" dedicated to selling its computer products. The TI 99/4 is most distinguished from the others by its Texas Instruments' Solid State Speech option, the same technology that made Speak 'N' Spell such a success.

Extensive writing about the advantages and disadvantages of personal computer systems is taking place in Byte, Creative Computing, InfoWorld, Personal Computing, Mini/Micro Systems, and in special issues of the journals of professional educational computing societies. It is beyond the scope of this article to summarize that literature. However, the primary test of which system is best will continue to be the sophistication of the software that it can support and the ease of its human interaction. Programs that used to run only on large machines are now being moved to small machines. Papert's (1980) LOGO, Starkweather's PILOT (Yob, 1977), and Dwyer's (1981) Soloworks are now running on personal computers, and their cost is drastically diminished. Computer companies and textbook publishers are also joining forces to create libraries of educational materials specifically designed for personal computers.

Hybrid systems. Authoring is difficult on a personal computer system. If one writes in a high-level authoring language, system overhead uses a painfully high percentage of computer resources. The most impressive personal computer programs are written in assembler language by top-flight computer programmers who are adept at getting the most out of each bit of memory and each cycle of the processor chip. But there are not many computer experts who can program this well, and hardly any educators. That is why the hybrid system looks so attractive today. In a hybrid system, materials are programmed on a mainframe where authors can take full advantage of on-line programming resources. Then, when they have been fully tested with students, the programs are down-line loaded for delivery in off-line microcomputer-based student learning stations.

The best hybrid example is the PLATO system. Materials are programmed on the main system in TUTOR, just as they always have been, except that when the programmer knows that the lessons will later be converted to run in MicroTUTOR, he uses the 8-bit data structures of the MicroPLATO station instead of the 60-bit words of the mainframe. When programs that were not originally planned to be moved to MicroPLATO are converted from TUTOR to MicroTUTOR, the conversion process can be painstaking and time-consuming.

Virtually any PLATO program can run off-line in the MicroPLATO station. The MicroPLATO terminal is the same as the on-line terminal except that it has more memory and an eight-inch, double-sided floppy disk drive. Control Data's Basic Skills Learning System has already been converted to MicroPLATO, and CDC is preparing complete courses in chemistry, physics, and FORTRAN that will run on MicroPLATO. The University of Delaware's GUIDO Music Learning System also runs on MicroPLATO.

Figures 41 and 42 show the configurations of on-line and off-line PLATO systems, respectively. The principal difference is that in the on-line system most processing takes place in the mainframe, and programs are stored in a central bank of hard disks; in the off-line system, all processing takes place in the microPLATO station, and programs are stored on local floppy disks.

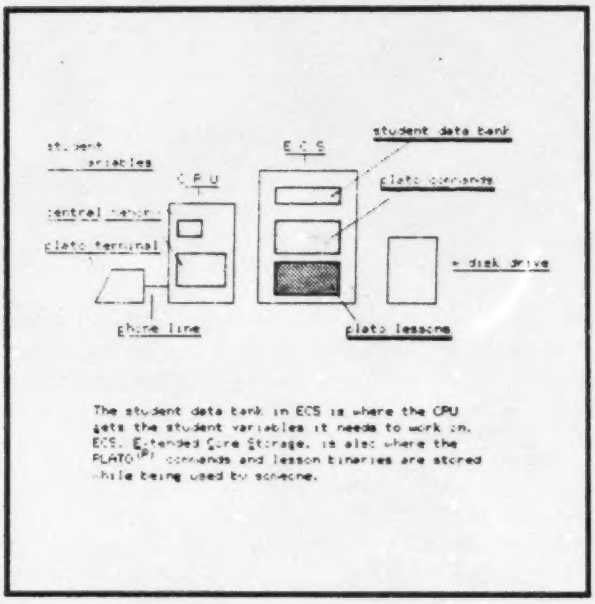

Figure 41. Configuration of the on-line PLATO system, by John Silver and Jay Green. Copyright © 1980 by the University of Delaware.

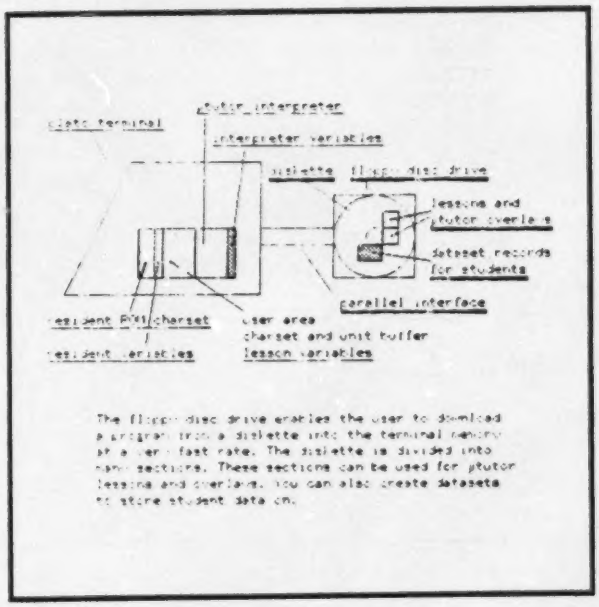

Figure 42. Configuration of the off-line MicroPLATO system, by John Silver and Jay Green. Copyright © 1980 by the University of Delaware.

CONTEMPORARY TRENDS IN COMPUTER-BASED EDUCATION

By reflecting upon the history, features, systems, and applications discussed so far, one can recognize five important contemporary trends in computer-based instruction. These are the growth of educational computing and dollars spent, the expansion of lesson libraries, networking experiments, peripheral development, and funding patteerns. Each of these trends is discussed in turn as follows.

Growth of Educational Computing and Dollars Spent

The amount of money spent on computing in education has steadily grown from practically nothing in 1960 to over one billion dollars annually today. This trend will continue in the 1980's. Enabling this growth is the development of new computer-based learning materials by universities, colleges, public schools, private companies, non-profit organizations, community colleges, and the military. Figure 43 shows the relative amounts of materials being developed by these groups, and figure 44 shows their sources of funding.

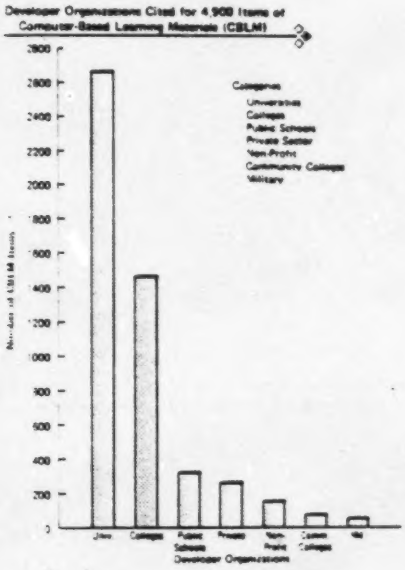

Figure 43. Developer Organizations Cited for 4,900 Items of Computer-Based Learning Materials.

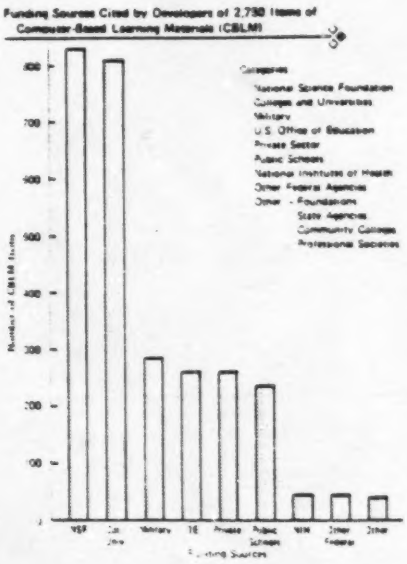

Figure 44. Funding sources Cited by Developers of 2,750 Items of Computer-Based Learning Materials.

*Figures 43 and 44 are taken from Hunter et al., Learning Alternatives in U.S. Education: Where Student and Computer Meet (Englewood Cliffs: Educational Technology Publications, 1975), pages 179 and 180, respectively. Used with permission.

Expansion of Lesson Libraries

The interaction of dollars spent and materials developed is resulting in a gradual expansion of lesson libraries. Kearsley analyzed the 1976 edition of the Index to Computer-Based Instruction and found that "there were 1,837 separate programs available covering 137 different subject matters. These programs originated from 219 different sources and used one or more of 17 types of instructional strategies. The programs were written in one of 76 author languages running on one of 116 different types of central processors" (Kearsley, 1976, p. 34). Today, the Index contains 4,868 programs.

Networking Experiments

The high cost of communications continues to be an obstacle to the widespread adoption of educational computing networks. Stand-alone personal computers have made it possible for more schools and even homes to use educational programs, but the distribution of an educational data base on floppy disks causes problems in the administration of instructional computing. Disks can be damaged, misplaced, or worn out; they are not easily updated when new versions of a program are released; and they make it difficult to keep student records for grading purposes. It is much better to use a central system that can update programs, keep student records, and provide communications between teacher and student, all as part of one automatic process.

An important experiment is underway at the University of Illinois. Jack Stifle, the designer of the programmable PLATO terminal, is leading a project whereby PLATO is being connected to a cable television network in an attempt to find out how many terminals could run on an interactive cable channel. Projections of the outcome range from two hundred to four thousand terminals. Given the low cost of cable communications, if thousands of terminals could in fact run on one channel, homes could easily be connected to an on-line data base.

A related experiment in Great Britain involves a new concept called "telesoftware." Brown (1981) explains how program libraries are maintained in a central data base on a large computer, and when users need programs from a library they dial up to the central computer, which down-line loads the programs into their home microcomputer. The programs then run locally in a cost-effective manner, without losing the advantage of on-line communications when needed.

Peripheral Development

Having external connectors for peripheral devices was mentioned above as an important characteristic of good computer-based instruction. During the past few years an exciting new line of peripherals has been introduced, and this trend will continue in the 1980's. Videodisc now makes it possible for computer programs to have instant random access to slides, motion pictures, and stereo music. Speech synthesizers have given computers the ability to talk; Votrax now sells a peripheral for the blind that interprets and speaks the communications between a computer and a terminal. Bit pads allow students to draw freehand whatever they want on the computer screen. Programmers are using bit pads to help make instructional displays, artists are using them in graphic design, and scientists are using them to digitize points on photographs and charts.

Digital music processors have given computers the ability to synthesize orchestral instruments by controlling harmonic spectra, envelopes, and special effects like tremolo, vibrato, and glissando. There are peripherals that can track eye movements, monitor heart rates, measure muscle contractions, and test electronic circuits. Peripherals are even being developed that can recognize speech. And the newly emerging field of robotics promises to extend the capability of instructional computers by giving them the capacity to manipulate physical objects.

Funding Patterns

An issue that is on everyone's mind today concerns sources of funding for CBI projects. With the massive cutbacks made by the Reagan administration to the education division of the National Science Foundation, which was the largest single source of funding for CBI in the 1970's, educators are now looking to industry and to the military for funding CBI research and development. Atari, Apple, and CDC have already established foundations from which educators can request support, and the military is expected to increase both the scope and the breadth of its involvement with CBI in line with its increasing need for training during the current build-up.

ISSUES IN THE FUTURE OF COMPUTER-BASED EDUCATION

This is both an exciting and a challenging time to be working in the field of computer-based instruction. It is exciting because computers have become so capable of helping us solve some fundamental problems in education, and because they are so much fun to use. It is challenging because with the horizons so active and so full of opportunity, one must study the field carefully and make the right decisions in order to be successful. There are six issues that are particularly important in the future of computer-based instruction. These are the decreasing cost of large systems, the increasing features of small systems, distributed versus central data bases, systematic design languages, models for CBI management, and institutional change. Each of these issues is discussed in turn as follows.

The Decreasing Cost of Large Systems

The largest and most expensive system on the market today is PLATO. The way in which its cost has declined over the past decade, even during a period of rampant inflation, is an important consideration in the future of computer-based instruction. In 1974, PLATO terminals cost $15,000; today, they are $2,900. Extended memory was one dollar for a sixty-bit word in 1974; today it is twenty cents. Figure 45 shows the effect of this trend on the hourly cost of delivering PLATO courseware. The cost of computer-based instruction is coming down while the cost of traditional instruction is going up.

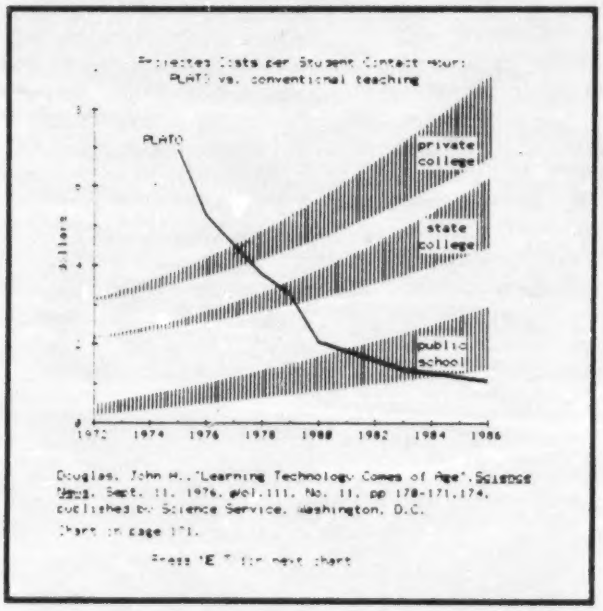

Figure 45. PLATO Cost Projection.

Increasing Features of Small Systems

In explaining this issue a comparison of the philosophies of large and small systems must be made. The philosophy of large systems, and particularly of the PLATO system, is to start with quality and to make available to the user the best in instructional computing. Cost is not a primary consideration, and given the trend discussed above whereby the cost of PLATO has decreased fivefold over the last ten years, it need not be. The philosophy of small systems, on the other hand, is to start with price and to configure systems based on what the consumer can afford. The decreasing cost of computing equipment affects small systems in a much different way than large systems. Whereas the decreasing cost of computer hardware is lowering the cost of large systems, it is increasing the features of small systems. This is because small systems start with price and make available what they can in an affordable range. As the features of large systems become affordable, the small systems add them. Soon the twain shall meet. When touch panels, high resolution graphics, animation, large memories, and networking are cheap enough, today's large systems and small systems will look pretty much the same. Today's large systems may well be tomorrow's small systems, and those writing courseware for large systems today are probably writing the courseware of the 1990's.

Distributed Versus Central Data Bases

An issue that goes hand-in-hand with the microelectronic revolution is the question of distributed versus central data bases. With cassette tapes, floppy disks, ROM cartridges, and videodiscs, instructional users can have their own local copies of educational programs and data bases, and they can plug them into their personal computers whenever they need them. The computer companies and publishing houses that are distributing educational information in this manner are currently creating such a distributed data base.

Whereas distributing educational information on personal storage media may look easy at first, hidden costs are high. Tapes and diskettes wear out and need to be replaced. ROM cartridges and videodiscs are read-only devices that cannot be updated when changes are needed to educational data. And the instructional management problems posed by personal storage media are immense. How are student records kept? What happens to the results of tests that students take? How do students find out what to do next in a computer-based course? Who do they ask for help when they have problems? When errors are found in existing programs, how do the students trade in their bad copies for good ones? How are new courses announced, and how do students enroll in them? All of these questions that were so easily answered on the mainframe system pose fundamental problems on personal computers. The answer may very well be some kind of hybrid system whereby the data base can remain intact on the large system, with personal computers connecting to it when they need to get new programs or store student records.

Systematic Design Languages

The greatest single cost in CBI is courseware development. Whereas hardware is relatively cheap and is getting ever cheaper, programmers are expensive and are getting more expensive. It takes a lot of programming time to produce good computer-based learning materials. For lessons that use graphics, animation, sophisticated judging, and response-sensitive branching, it typically takes from one hundred to two hundred hours of programming time to produce one hour of instruction.

Efforts are underway to reduce this ratio by creating systematic design languages that will allow educators to create instructional lessons without actually writing computer code. Many systems already have graphics editors that allow programmers to draw pictures on the screen with light pens or bit pads, and then the system automatically generates the code needed to reproduce those pictures in an instructional lesson. Systematic design languages will extend this concept to include not only graphics but also judging, branching, record keeping, and instructional management. Systematic design languages represent the next stage in the development of CBI authoring systems. Not only will they reduce the amount of time that it takes programmers to make lessons, but they will also increase the number of people that can make good lessons because they will be easier to learn and easier to use than the present generation of authoring languages.

Models for CBI Management

Computer-based instruction is a unique environment that requires its own special set of policies and procedures. Those establishing CBI sites are well advised to seek out the advice of those who have gone before them. Before setting policies and procedures at Delaware the advice of Dr. Donald Bitzer, the inventor of PLATO at Illinois, and Dr. Frank Propst, his associate director, was sought; their advice allowed Delaware to avoid many potential problems. Steinberg (1977) has documented the problems encountered at several CBI sites so that they may be avoided in the future.

There are ten key factors that must be considered in adminstering computer-based education. These are faculty leadership, system selection criteria, centralized control of resources, independence in project management, development of new materials, clear statement of mission, financial rationale, staff development, publication of research, and effeciency in on-line project management. Although it is beyond the scope of this paper to explain the interaction among these factors, it is discussed elsewhere (c.f. Hofstetter, 1981).

Emergence of a New Profession

It is appropriate to conclude this paper with a discussion of institutional change. Computer-based techniques are having a profound impact upon education as we know it today. A whole new profession is emerging that involves teachers as subject matter experts and on-line advisors, curriculum developers as lesson designers and computer programmers, and students as lifelong learners who will have access to the delivery system in their homes. Just with the technology that we have now, Molnar (1975) has already estimated that 25% of higher education can be delivered by computers. The fact that PLATO's GED system can prepare a student to take high school equivalency tests is an indicator of how much secondary education can be computer-based, as is the Basic Skills Learning System for elementary education.

There is an ever-increasing body of research documenting the effectiveness of computer-based instruction. It is beyond the scope of this paper to summarize that research, but there are bibliographies with summaries of the content of the articles both for PLATO (Hofstetter, 1980) and CBI systems in general (Kulik et al., 1980). Computers have been found to be effective tools for increasing achievement, decreasing learning time, motivating students, and conducting research into learning itself. Recognizing these benefits, the Subcommittee on Science, Research, and Technology of the Committee on Science and Technology of the U.S. House of Representatives (1980) has concluded that:

> "...a close look at the whole educational enterprise--including industrial and military training, continuing and professional education, and special education, as well as teaching in traditional classrooms--reveals that information technology has already made significant penetration into these activities. The rate of the penetration has not been as rapid as many had hoped or predicted ten or twenty years ago. However, there is virtual unanimity of opinion that information technology will be an increasingly important part of education at all levels..."

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